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STEAM-WATER IODINE PARTITIONING EXPERIMENT INSTALLATION AND COMMISSIONING

Report No. 87-320-K

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ABSTRACT

A facility for controlled discharge of high temperature, high pressure water has been installed in the Thermo-Fluids Laboratory. Commissioning for the Steam-Water Iodine Partitioning Experiment (SWIPE) has been completed.

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24-266-40153	824.7	February 11, 1988	87-320-K

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EXECUTIVE SUMMARY

STEAM-WATER IODINE PARTITIONING EXPERIMENT INSTALLATION AND COMMISSIONING

I.G. Elphick , J.H. Russell
Mechanical Testing & Development Section
Mechanical Research Department

The Thermo-Fluids Unit has installed and commissioned a facility for research into flashing two-phase jets. Although primarily intended for the Steam-Water Iodine Partitioning Experiment (SWIPE), it can be used for other studies requiring a two-phase jet.

The major components of the facility are a pressure vessel, separation equipment and associated instrumentation. The pressure vessel has a capacity of 50 liters and it is capable of acheiving pressures up to 3MPa and temperatures up to saturation (235°C). The discharge assembly, including valve and nozzle, was designed to ensure that flashing will occur very close to the nozzle throat. The separation equipment effectively removes the droplets from the steam and condenses the steam for sampling. A microcomputer-based data acquisition system logs temperatures and pressures during a test.

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TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 DESCRIPTION OF THE FACILITY	1
3.0 INSTALLATION & COMMISSIONING	2
4.0 CONCLUSION	5
Figures	6
Distribution	last page

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To Dr. R.A. Brown
Manager, Nuclear Studies & Safety
Design & Development - Generation

STEAM-WATER IODINE PARTITIONING EXPERIMENT INSTALLATION AND COMMISSIONING

1.0 INTRODUCTION

The Thermo-Fluids Unit has completed the commissioning of a pressurized water blowdown facility for containment research. The initial purpose for this facility was to study iodine partitioning in unbounded critical two phase flows. This report will describe the facility, the commissioning and the modifications that relate to SWIPE (Steam Water Iodine Partitioning Experiment). This experiment was performed under contract with the Nuclear Studies and Safety Department.

2.0 DESCRIPTION OF THE FACILITY

The facility has been installed and commissioned in the Fluids Laboratory of the Mechanical Testing and Development Building. It can be used for applied or fundamental research related to containment studies. The water is heated and pressurized in a 50 liter pressure vessel rated to 3 MPa. Discharge from the vessel is controlled by a shutoff valve and a nozzle. Both the reservoir and nozzle are instrumented for temperature and pressure measurements. The pressure vessel is mounted on a weigh scale which is used to measure the discharge during blowdown. This is important for mass balance and for determination of critical discharge. Nitrogen cover gas is available for creating sub-cooled conditions in the vessel.

The following photographs show the important details of the facility as it was installed before commissioning in January, 1987. Shown in Figure 1 is the pressure vessel mounted on the weigh scale. Figures 2 & 3 are views of the separation equipment and the shielding plates. The temperature and pressure instrumentation was connected to a microcomputer (Figure 4). During a blowdown the temperatures and pressures were recorded on floppy disk. Heating tape and insulation surround the separation equipment (Figure 5). The temperature of the separator was maintained at about 100°C to minimize condensation of water vapour from the two-phase jet. A demister and water trap were located above the separator to remove any unflashed aerosols and trap any condensed vapour (Figure 6). The condensed vapour was funneled

into a collection beaker (Figure 7). Figures 8&9 show a two-phase jet leaving the nozzle and entering the separator. Deionized water with a conductivity of 5μ mho is pumped into the vessel (Figure 10). Figure 11 shows the hydraulic connections: the water inlet (bottom), the vent line (upper right) and the nitrogen inlet (upper left). The vessel temperature was measured using a type-K thermocouple installed in a thermowell (right); the pressure was measured with a strain-gage transducer and a pressure gauge (left), as shown in Figure 12. Temperature and pressure were measured close to the nozzle throat using a type-K thermocouple and a strain-gage transducer (Figure 13). The first nozzle that was installed was a long tube 1.5mm in diameter with a conical exit (Figure 14).

3.0 INSTALLATION & COMMISSIONING

The pressure vessel and separation equipment were moved into the Research Division from the University of Toronto in the fall of 1986. There were a few tasks to be completed in preparation for commissioning.

The data acquisition system was upgraded. The new system was based on an IBM PC/XT compatible with a commercially available data acquisition software package. The menu driven DT/NOTEBOOK software and associated interface cards for thermocouples and high-level inputs were purchased.

The nozzle design was improved. The objectives were to control and measure the reservoir temperature and pressure, the location of flashing, and the temperature at the nozzle tip. It was also required that the nozzle outer geometry would allow air entrainment into the two-phase jet. It was estimated that a 1.5 mm inside diameter would allow at least 45 minutes of run time. The nozzle, as shown in Figure 14, had a length-to-diameter ratio (L/D) of 100. The temperature at the nozzle tip was measured with a thermocouple spot-welded to the outer surface of the nozzle. The pressure was measured using a static pressure tap at the nozzle tip.

A meeting was held in the Research Division, (fall 1986) to determine the best method of chemical analysis. It included representatives of the Chemical Analysis Section, Nuclear Studies and Safety Department and the Thermo-Fluids Unit. Various analytical techniques were discussed for detection of iodine and cesium in solution. The limits of detectability for these techniques were investigated. Standard samples of Cesium and Iodine in solution were prepared by the Chemical Analysis Section. Table 1 summarizes the results of the investigation.

Table 1
Detectability Limits

Analysis Technique	Chemical Species	Tolerance
NAA 10ml sample irradiated for 6min @ 20kW	Iodine	±0.04ppm
NAA 100ml passed through 0.5ml mixed bed resin	Iodine	±0.005ppm
AAS flame test	Cesium	±0.020ppm
FAAS flameless test	Cesium	±0.002ppm

After experimenting with the long tube nozzle, it was found that a shorter nozzle was needed to satisfy the requirement that flashing occur at the nozzle exit or throat. The second nozzle is shown in Figure 15. During commissioning of this nozzle, careful measurements showed that there was still considerable pressure drop between the pressure vessel and the pressure tap at the nozzle (Figure 16). It was concluded that this pressure drop was due to flashing between the pressure vessel and the nozzle. This was supported by two facts: (1) hydraulic losses for a cold blowdown were negligible and (2) the pipes and valve between the tank and nozzle were not of uniform diameter, ie there were steps in cross-sectional area. It is likely that these step changes would promote premature flashing due to pressure drop. It was then decided to replace the valve assembly and nozzle, with a 22mm diameter smooth inlet valve assembly and a custom brass nozzle, with a short transition from (22mm to 1.2mm in 3mm) (Figures 17-22). A blowdown with this new assembly showed that the vessel pressure and the nozzle inlet pressure were in good agreement (Figure 23). It was concluded that flashing did not occur until after the nozzle inlet. This assembly was accepted for the Steam-Water Iodine Partitioning Experiment (SWIPE).

The next series of commissioning tests involved blowdowns with the separation equipment to determine optimum running times. For a 3MPa saturation blowdown, IPEX06, the nozzle tip was 3" from the separator and after 300s blowdown the condenser collected 75ml of condensate. In the following test, the nozzle tip was placed at the separator inlet and after 200s blowdown 1250ml of condensate was collected. For the next tests, the nozzle tip remained at the separator inlet and the reservoir subcooling was varied. For test IPEX07 the pressure was maintained at 3MPa with nitrogen cover gas and the temperature was set to 110°C. There was no appreciable concentration of steam but essentially a water jet issued from the nozzle. For the next test, IPEX08, the pressure was maintained at 3MPa and the temperature was set to 150°C. After a blowdown of 100s, 200ml of condensate was collected. Since the chemical analysis required at least 200ml of condensate, it was concluded that reservoir temperatures at 3MPa could not be less than 150°C. The final nozzle commissioning test was again performed at 3MPa saturation but the separation equipment was removed

to view the jet. Figure 24 shows a typical jet for reservoir at 3MPa saturation. In one case it was noticed that the jet was split (Figure 25). A microscopic examination of the nozzle tip showed a burr which was probably left behind after machining. The burr was removed by lightly sanding and subsequent observation showed that the jet was axisymmetric.

The following series of tests IPEX10 to IPEX16, were production runs with various concentrations of Cesium and Iodine added to the deionized water in the pressure vessel. These tests were a parametric evaluation of thermohydraulic and chemical initial conditions on iodine partitioning. For this series of tests, the nozzle tip was located at the separator opening. Consequently air was drawn into the separator. The next series of tests, IPEX 20 to 23, was a repeat of selected tests from the previous series. However, the nozzle tip and separator inlet were sealed to prevent air from entering the separator (Figure 26). For this series of tests, the steam flow through the condensers was much greater and, as a result, condensed water vapour in the form of aerosol escaped through the bottom of the condenser. To collect these, a demister was installed downstream of the second condenser (Figure 27). To facilitate sampling liquid from the pressure vessel when the temperature was greater than 100°C, a stainless steel cooling coil was attached to the sampling port (Figure 28). Table 2 summarizes the IPEX tests 1-23.

Table 2
IPEX Commissioning & Production Runs

TEST No.	TYPE	CONDITIONS	COMMENTS
IPEX 1-5	commissioning	P = 3 MPa T = 20, 234 °C	
IPEX 6-9	commissioning	P = 3 MPa T = 110, 150, 234 °C	
IPEX 10-16	production	P = 3 MPa T = 150, 234 °C pH = 7, 10 I_o = 10^{-6}, 10^{-4} g/g Cs_o = 10^{-6}, 10^{-5}, 10^{-4}, 10^{-3} g/g	nozzle tip @ separator opening air entrainment
IPEX 20-23	production	P = 3 MPa T = 234 °C pH = 7 I_o = 10^{-4} g/g Cs_o = 10^{-5}, 10^{-4}, 10^{-3} g/g	nozzle fastened to separator no air entrainment

4.0 CONCLUSION

The pressurized water blowdown facility has been sucessfully installed and commissioned. Although the primary focus was on the SWIPE program, this facility can be used for other studies requiring a two-phase jet. The data from the SWIPE program will appear in subsequent reports.

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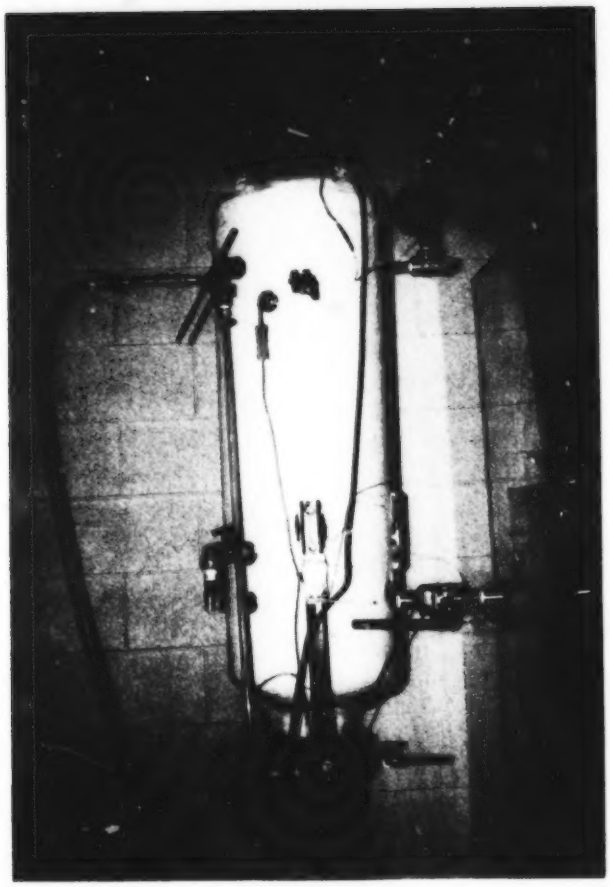

Figure 1: Pressure Vessel Mounted on Weigh Scale

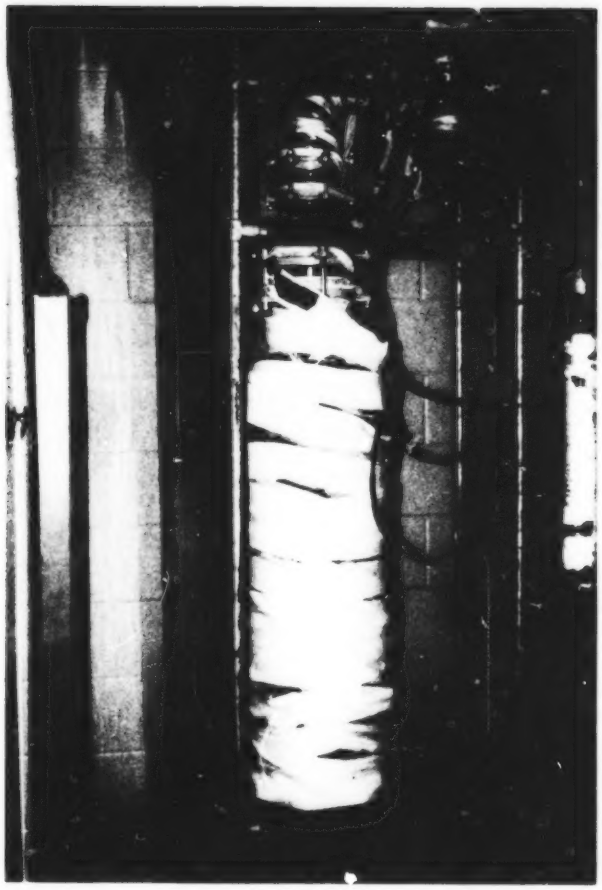

Figure 2: Separation Equipment and Shielding Plates

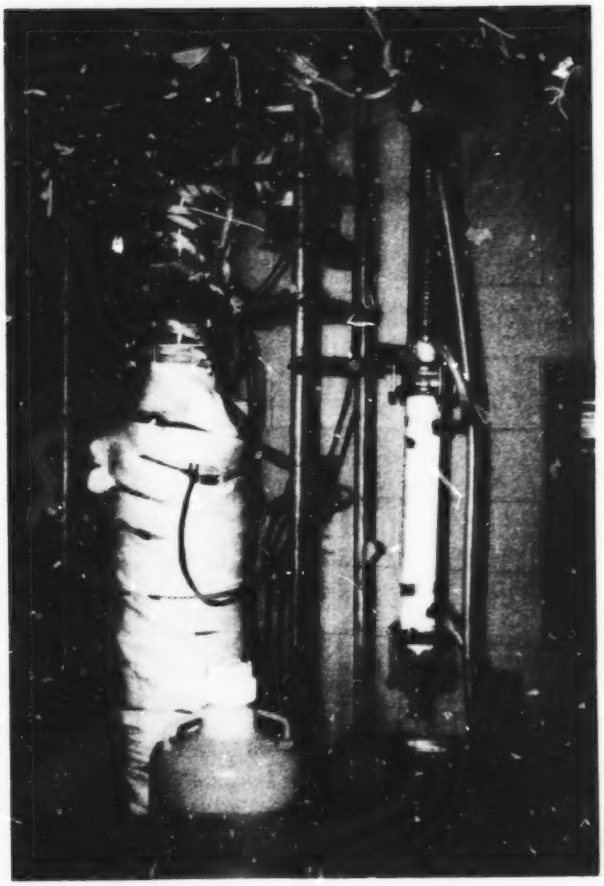

Figure 3: Separation Equipment and Shielding Plates

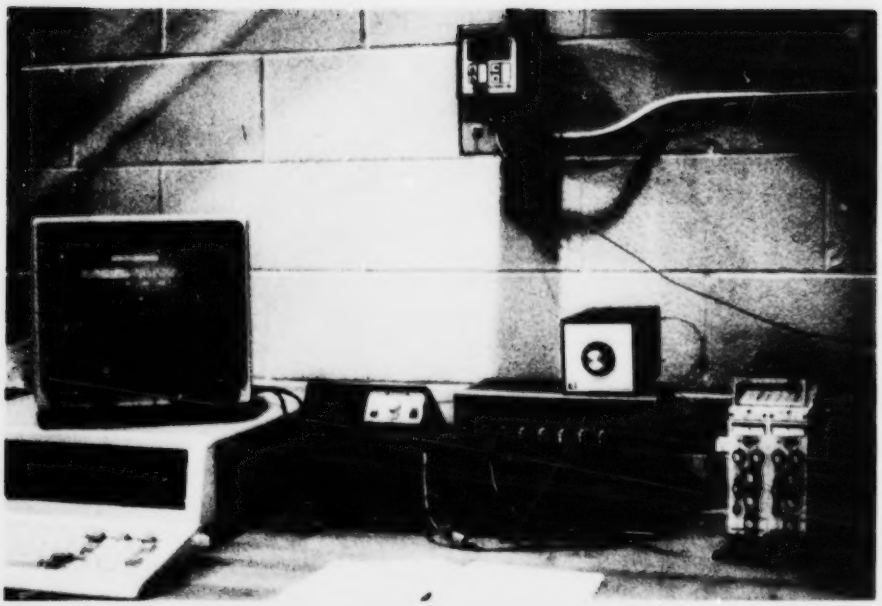

Figure 4: Data Acquisition System

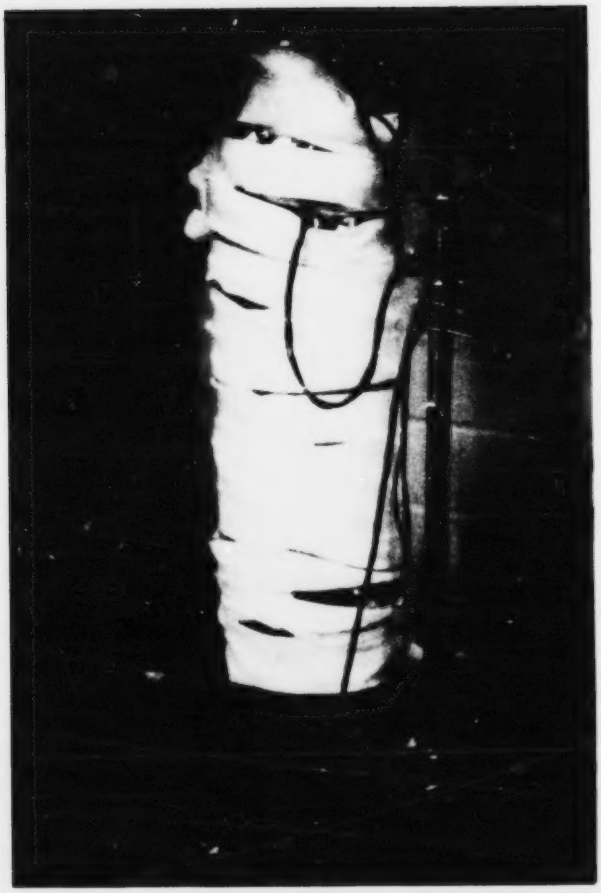

Figure 5: Heating Tape and Insulation

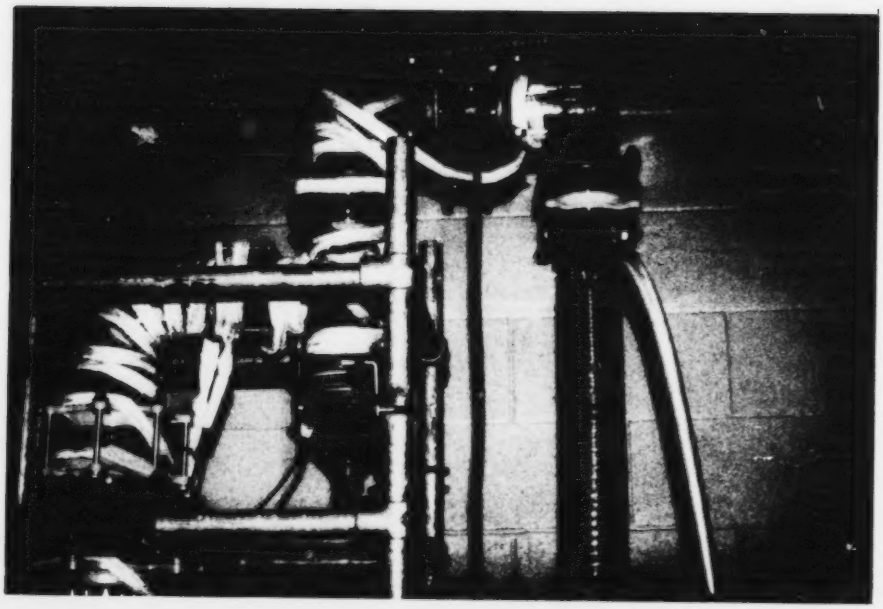

Figure 6: Demister and Water Trap

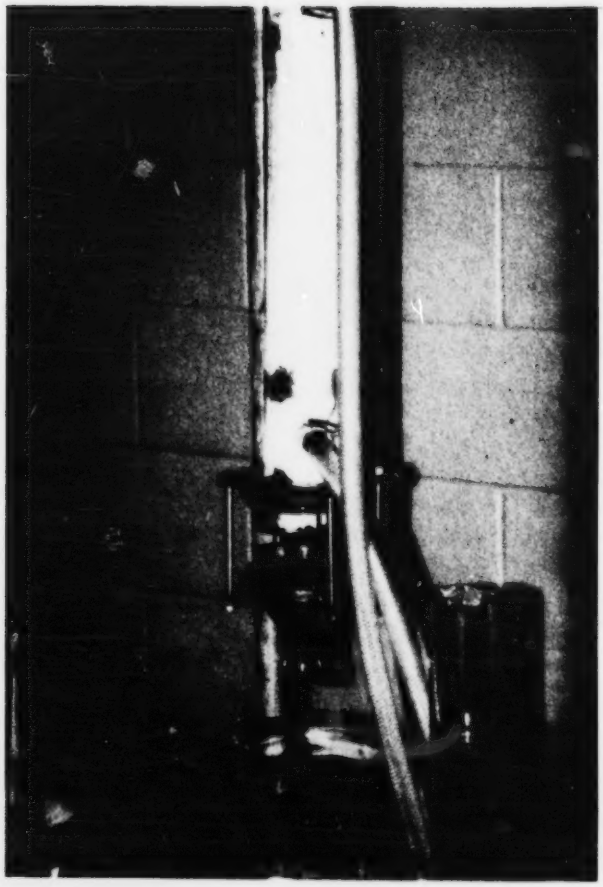

Figure 7: Collection Beaker

Figure 8: Two-Phase Jet

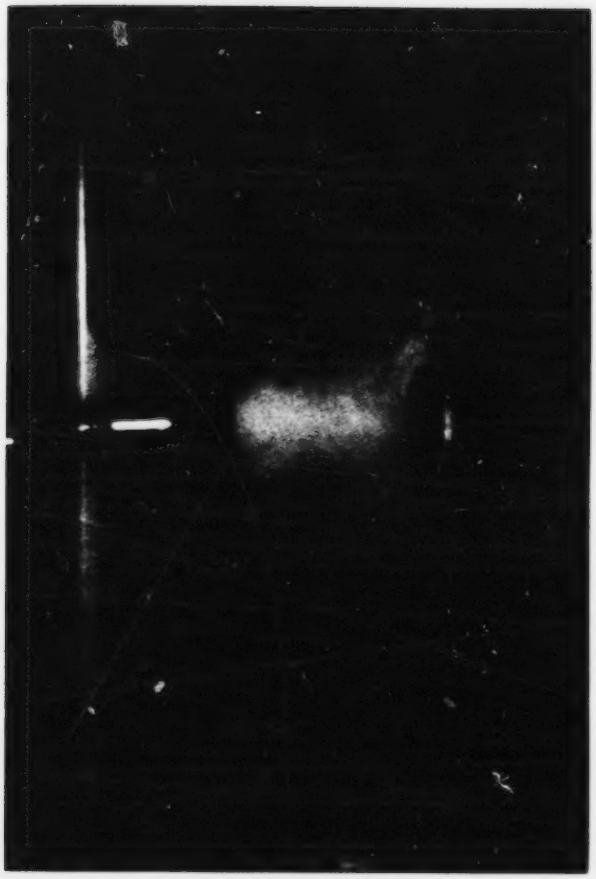

Figure 9: Two-Phase Jet

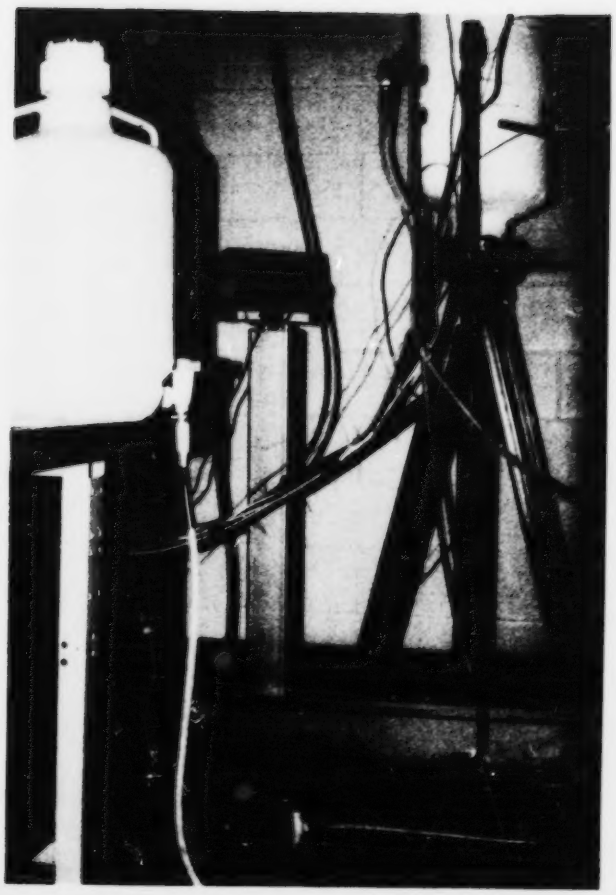

Figure 10: Loading Deionized Water into Pressure Vessel

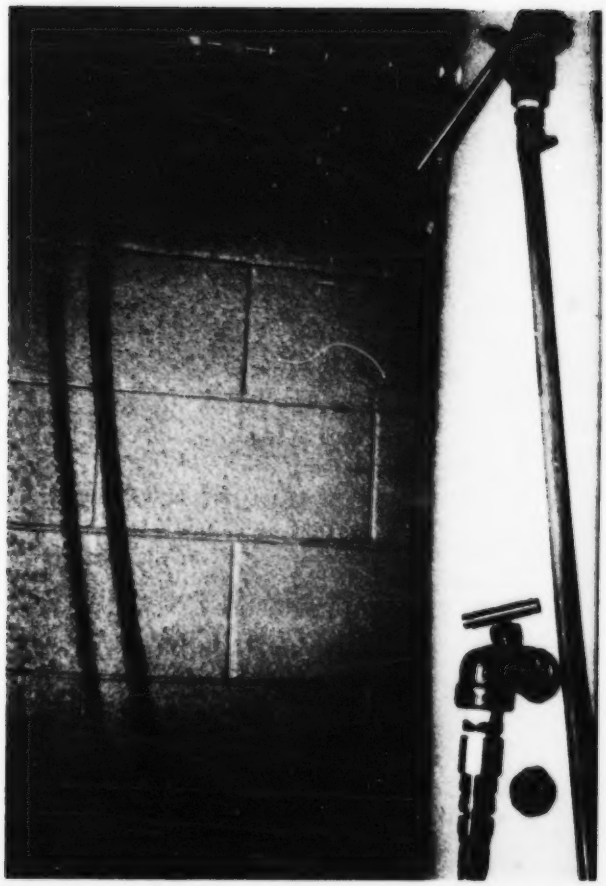

Figure 11: Hydraulic Connections

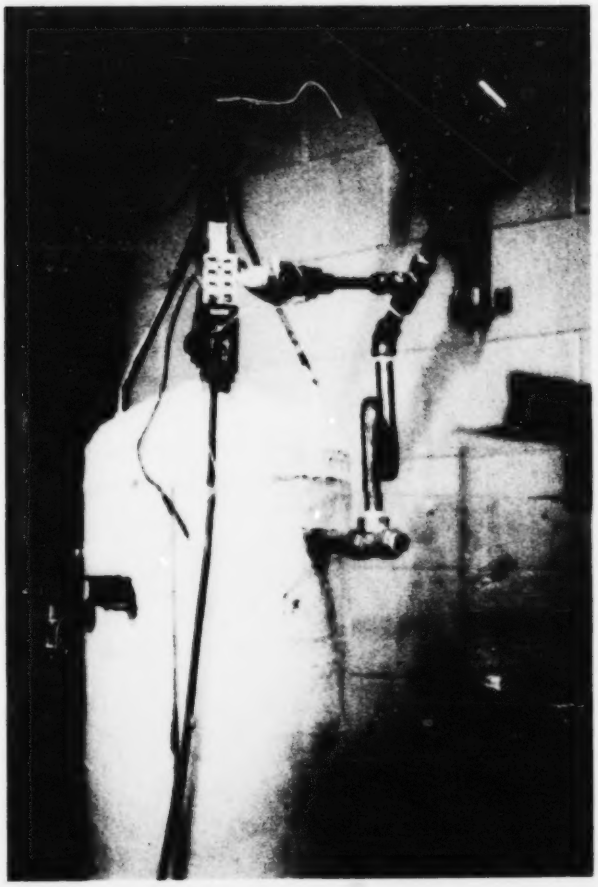

Figure 12: Measuring Temperature and Pressure in the Vessel

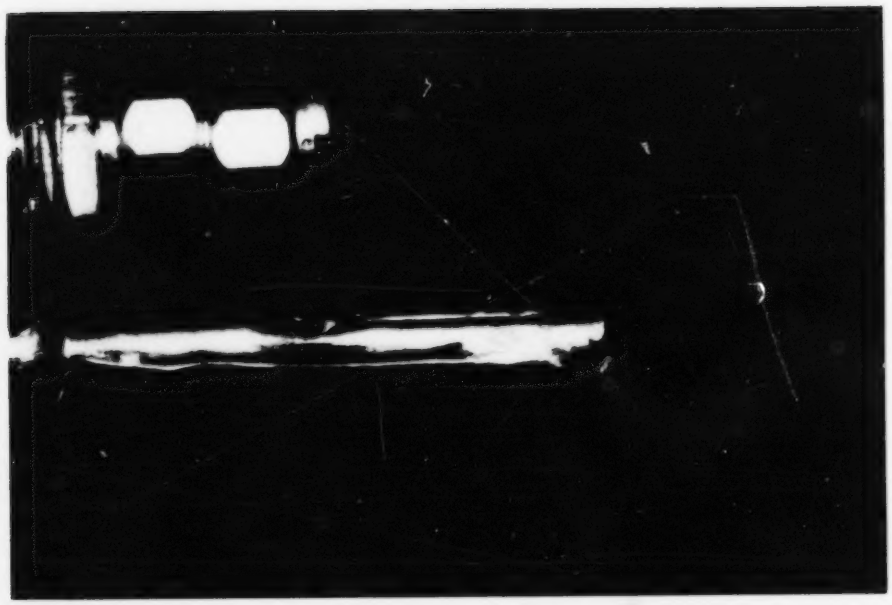

Figure 13: Measuring Temperature and Pressure at the Nozzle

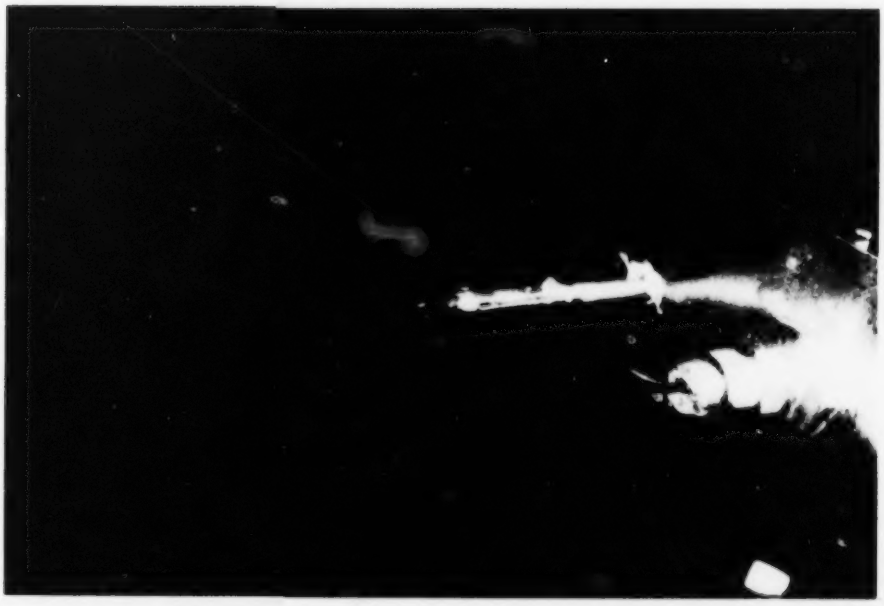

Figure 14: First Nozzle - Long Tube

Figure 15: Second Nozzle

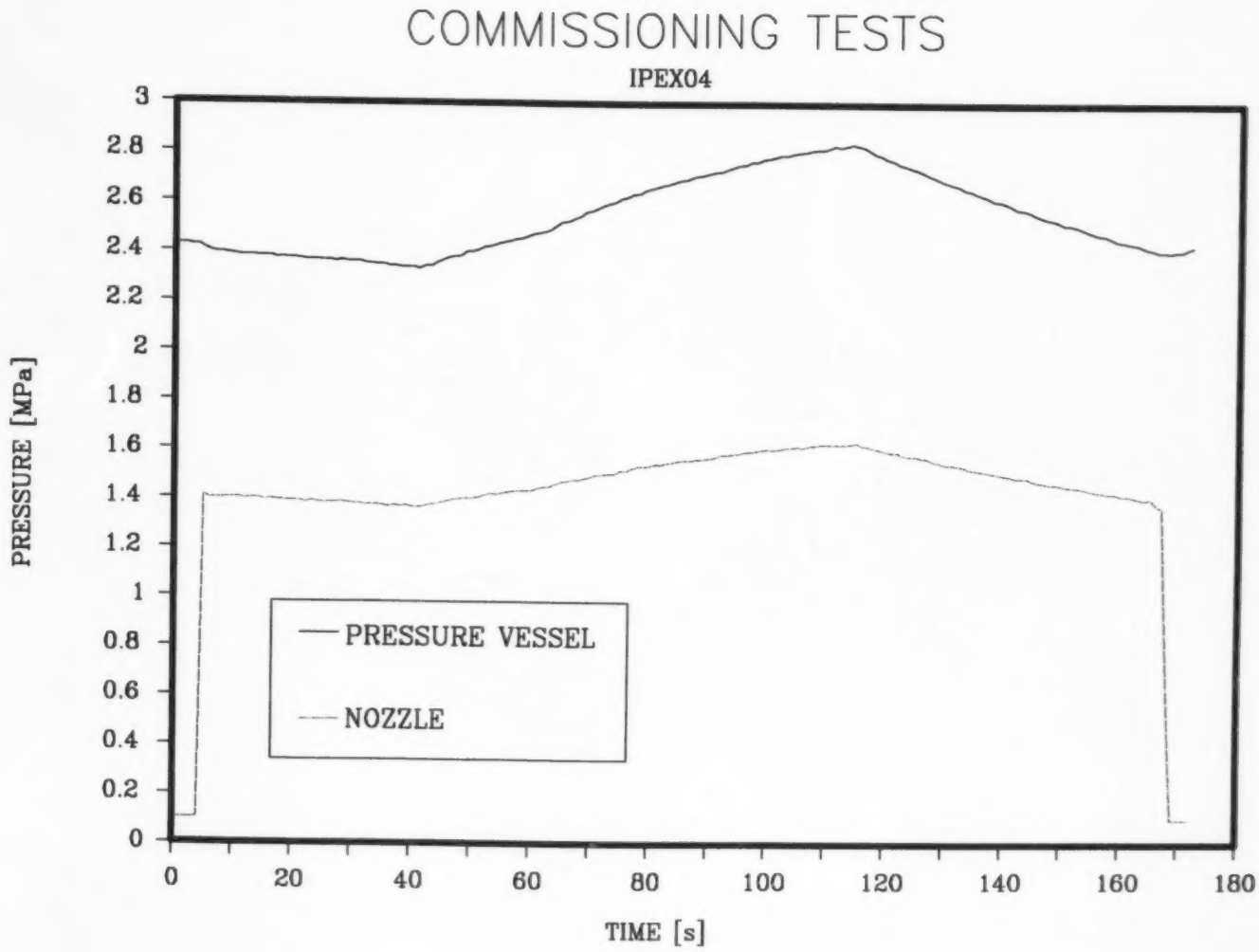

Figure 16 : Blowdown with Second Nozzle

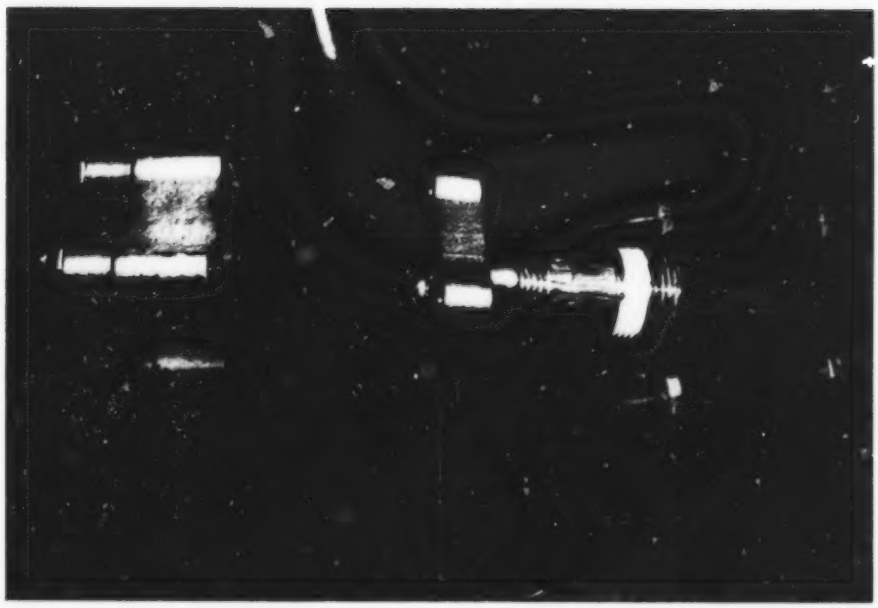

Figure 17: Discharge Valve and Connecting Flange

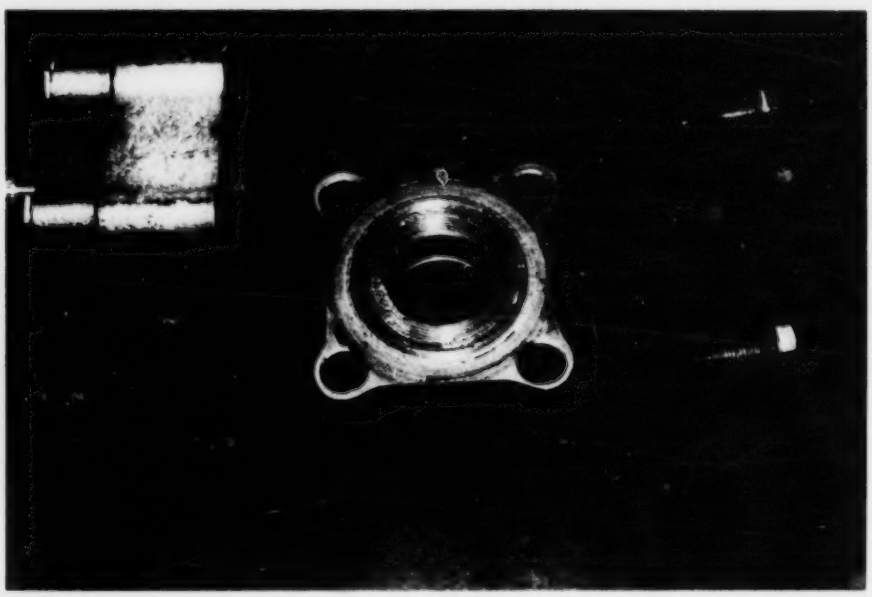

Figure 18: Step in I.D. of Flange

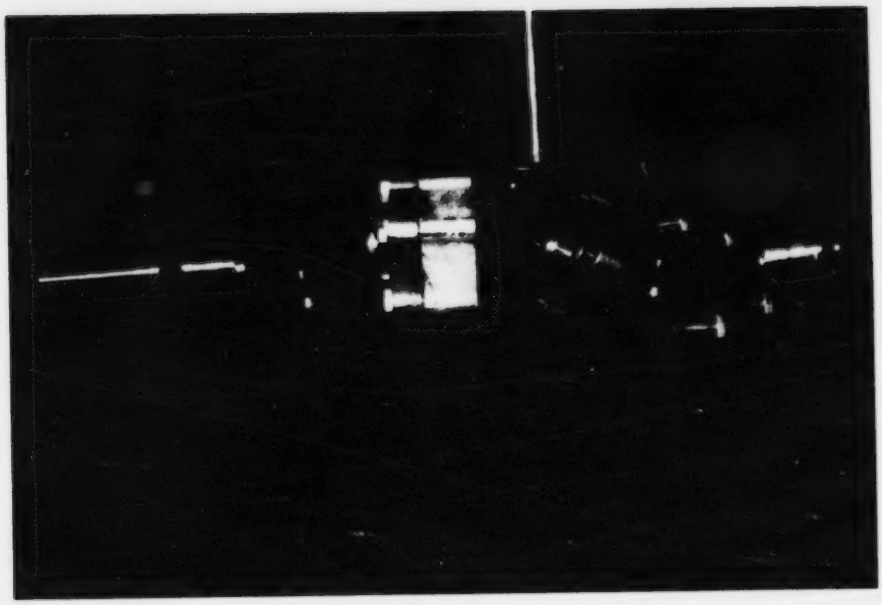

Figure 19: New Discharge Assembly

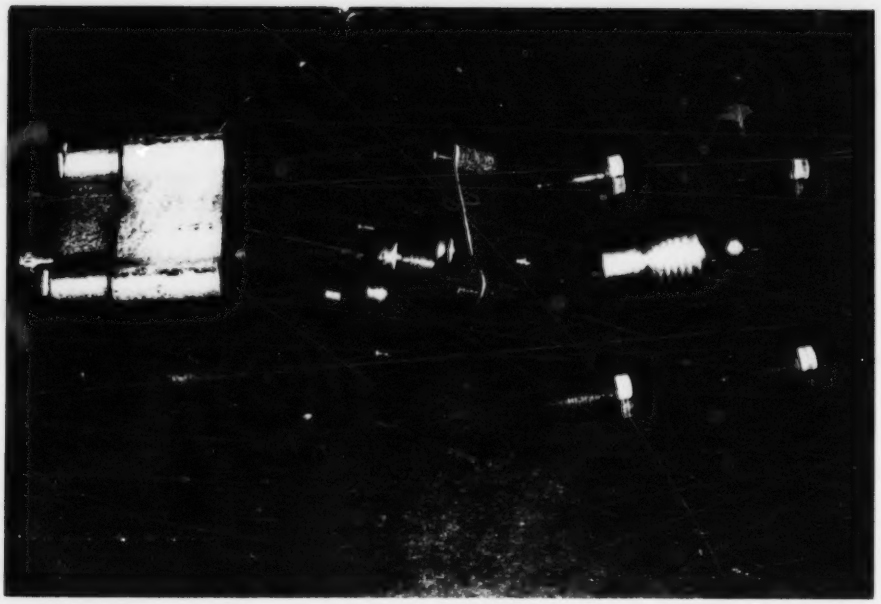

Figure 20: Spacer Ring for Flange

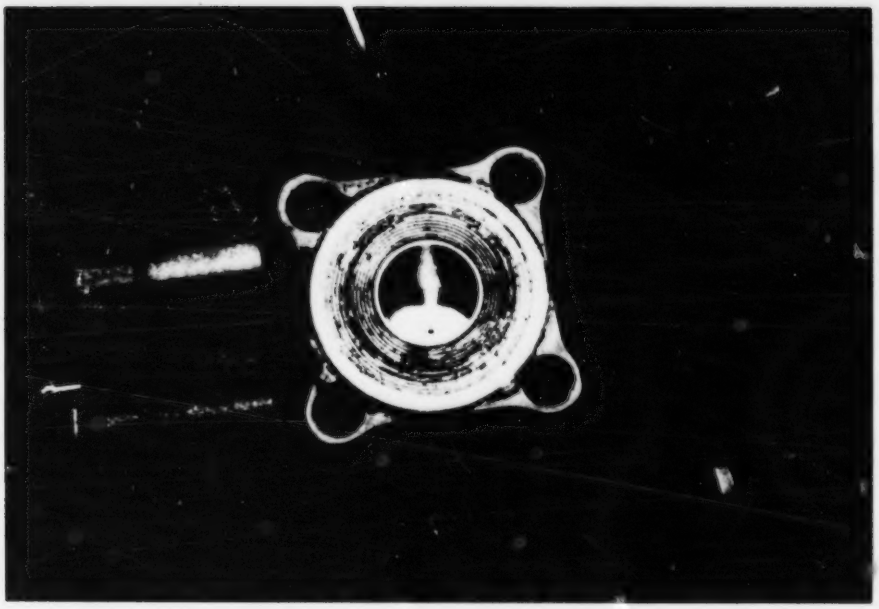

Figure 21: Inside View of Nozzle

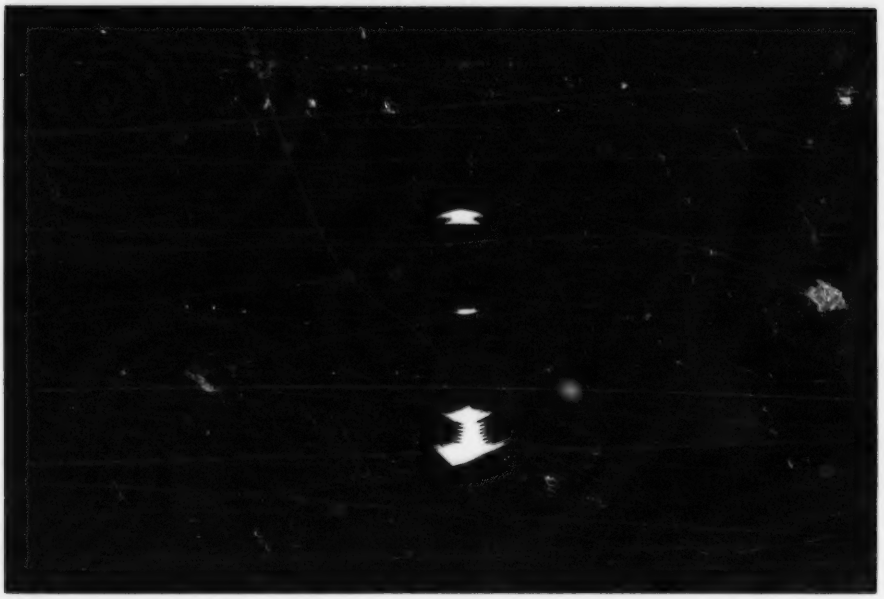

Figure 22: Tapered Inlet Pipe

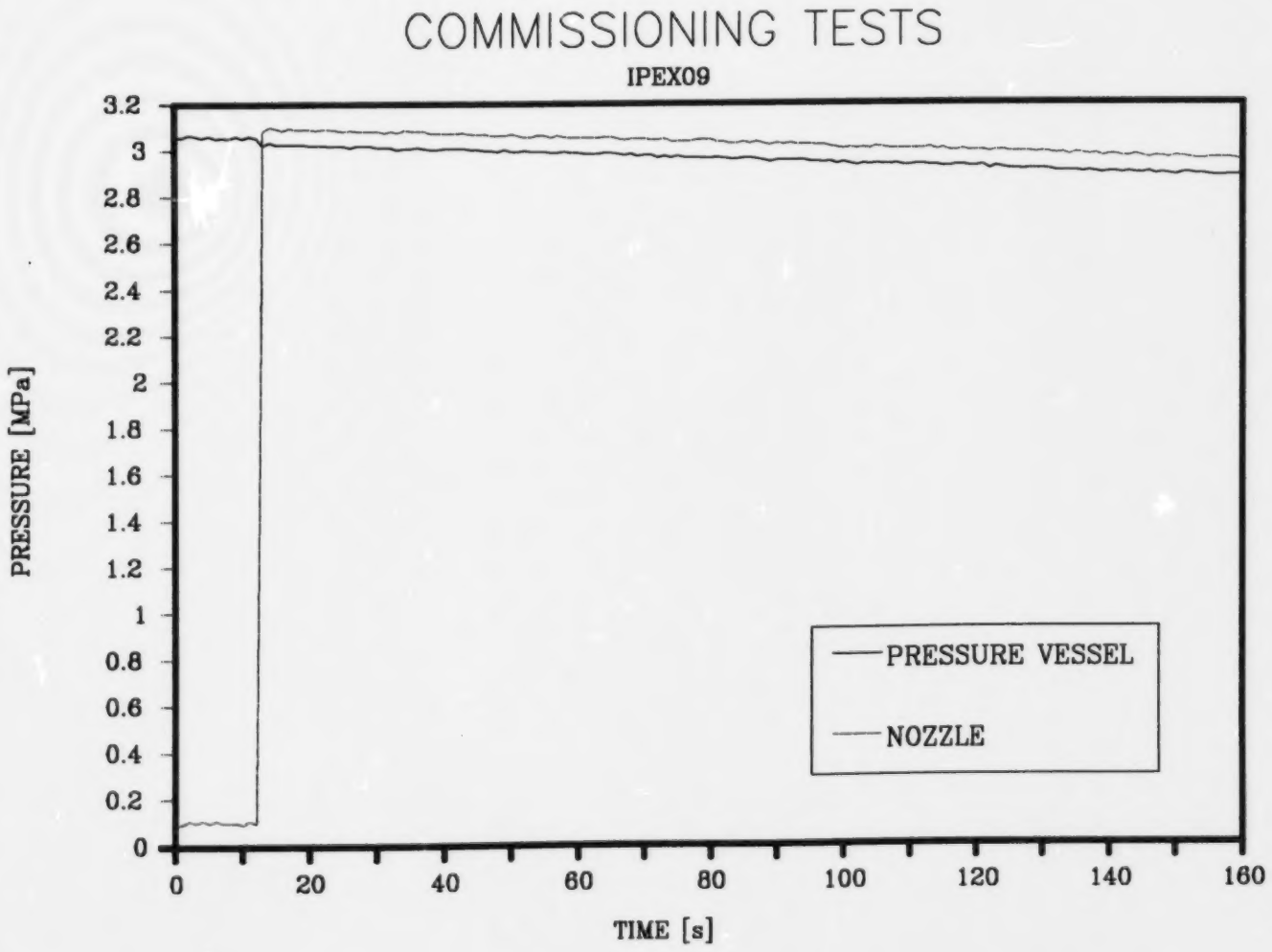

Figure 23 : Blowdown with Third Nozzle

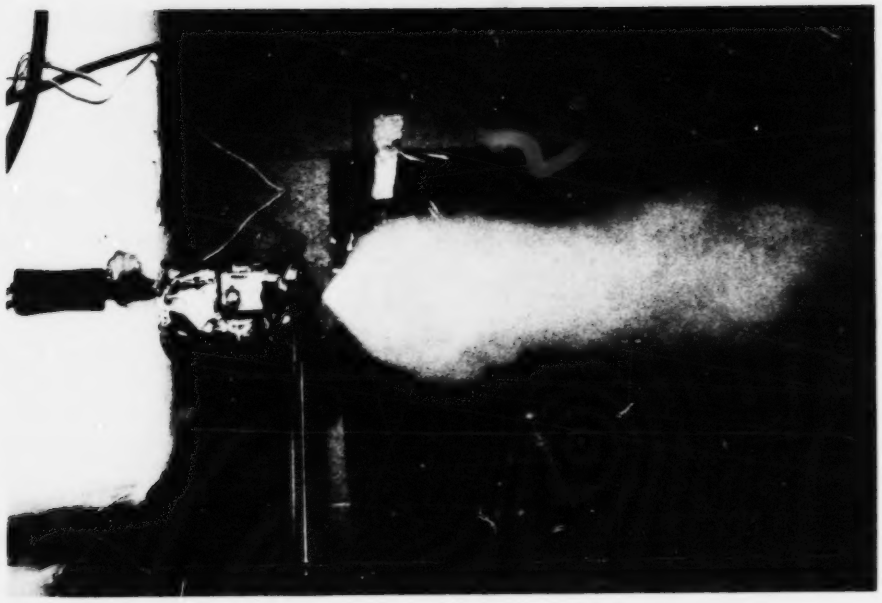

Figure 24: Typical Jet for 3MPa Saturation Reservoir Conditions

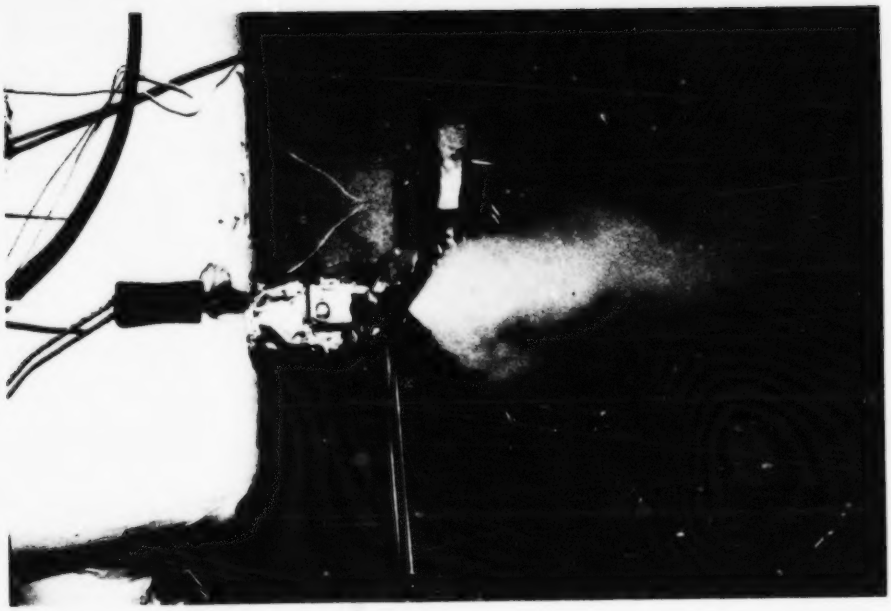

Figure 25: Case of the Split Jet

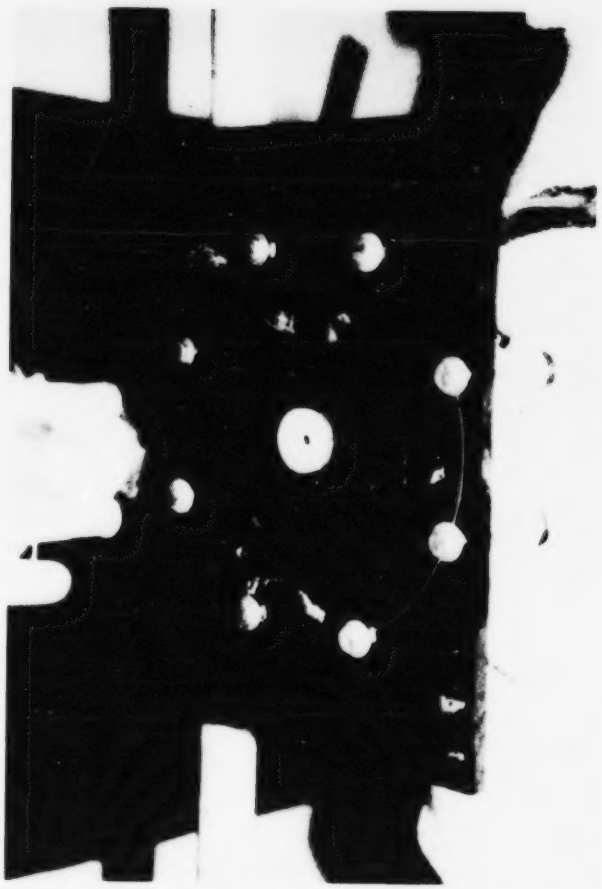

Figure 26: Separator Cover

Figure 27: Final Demister

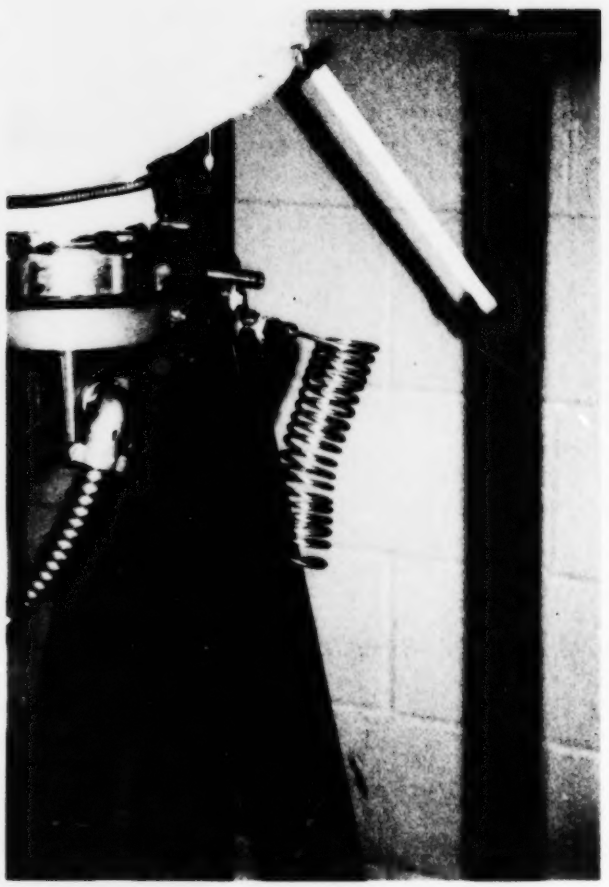

Figure 28: High Temperature Sampling Port